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Engineering Design File

Evaporation Pond Sizing with Water Balance and Make-up Water Calculations

Idaho National Engineering and Environmental Laboratory

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ENGINEERING DESIGN FILE

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5. Summary:

The U.S. Department of Energy (DOE) authorized a remedial design/remedial action for the Idaho National Engineering and Environmental Laboratory (INEEL) including the Idaho Nuclear Technology and Engineering Center (INTEC) in accordance with the Waste Area Group (WAG) 3 Operable Unit (OU) 3-13 Record of Decision (ROD). The ROD requires contaminated surface soils to be removed and disposed on-Site in the INEEL CERCLA Disposal Facility (ICDF). Infrastructure associated with the landfill includes an evaporation pond system and a leachate collection system. This engineering design file (EDF) provides the design calculations and assumptions for sizing of leachate evaporation ponds.

The pond area and depth were determined based on the need to evaporate all ICDF landfill leachate, precipitation falling directly on the ponds, and additional flows totaling 30,000 gallons per month from March through November of each year from such sources as washdown water for trucks and equipment and purge/development water. The evaporative surface area was selected to allow evaporation of the average leachate production and precipitation onto the pond. Then the pond depth was selected to provide storage for excess leachate and precipitation that may accumulate if the worst-case leachate and precipitation were to occur for 3 years in a row following an average year.

The results of the computations showed that a total evaporation pond area bottom area of 88,000 ft^2 with depth of 64 in. will be adequate to handle the worst-case conditions. This depth provides a minimum freeboard of 24 in. Raw make-up water necessary to keep pond sediments submerged was found to be between 1 and 6 gallons per minute (gpm) over a period ranging from 3 to 6 months, depending on the evaporation surface area allowed and the assumed pond inflow conditions. Sensitivity analyses checked pond capacity under back-to-back 25-year, 24-hour storm volume estimates, as well as freeboard adequacy under design wind conditions.

6. Review (R) and Approval (A) and Acceptance (Ac) Signatures:
(See instructions for definitions of terms and significance of signatures.)

	R/A	Typed Name/Organization	Signature	Date
Performer		Dean Bose/ CH2M HILL	Dean Bose	05/14/02
Checker	R	(Same as Independent Peer Reviewer)		05/14/02
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ABSTRACT

Evaporation ponds at the INEEL CERCLA Disposal Facility are sized to meet performance specifications such that the pond is designed for maximum expected inflow while minimizing both pond surface area and make-up water. Further, pond sediments must remain submersed at all times. Anticipated make-up water needs were calculated for a sustained dry period.

Conservative inputs were used in the calculations to evaluate pond performance under extreme inflow conditions. Pond freeboard was checked for overtopping against design wind conditions.

CONTENTS

ACRONYMS

ASAE	American Society of Agricultural Engineers
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
DOE	Department of Energy
EDF	engineering design file
EPA	Environmental Protection Agency
GCL	geosynthetic clay liner
gpm	gallons per minute
HDPE	high-density polyethylene
HELP	Hydraulic Evaluation of Landfill Performance
ICDF	INEEL CERCLA Disposal Facility
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
NOAA	National Oceanic and Atmospheric Administration
OU	operable unit
ROD	Record of Decision
SPC	specification
SSSTF	Staging, Storage, Sizing, and Treatment Facility
TAN	Test Area North
USACE	U.S. Army Corps of Engineers
WAG	waste area group

Evaporation Pond Sizing with Water Balance and Make-up Water Calculations

1. PURPOSE/OBJECTIVE

An evaporation pond will be used at the INEEL CERCLA Disposal Facility (ICDF) to treat leachate and process water. The size of the evaporation pond was determined based on the projected needs of the site as defined by Section 5.6.4.1 of the ICDF Performance Specification (SPC-332). The requirements are that the evaporation pond, consisting of two individual cells, be designed with sufficient capacity for landfill leachate, precipitation directly into the evaporation pond, and additional inflows (e.g., washdown water for trucks and equipment, and purge/development water totaling 30,000 gallons per operating month [i.e., March through November]). The pond is required to treat maximum expected inflow while minimizing both pond surface areas. The specifications also require that pond sediments remain submerged at all times. The correctly sized pond demonstrates the greatest reduction in water surface depth without the pond going dry. Additional make-up water will be used if necessary to keep the sediments submerged. Calculation of the potential range of make-up water needed under various design scenarios is also performed in this engineering design file (EDF).

Versatility and conservatism were important factors when sizing the evaporation ponds. The versatility of the two pond system allows for consolidation of leachate into a single pond during the dry season to clean out and maintain the other. Conservative sizing of the pond allows for both storage volume for large inflows (such as design storm events in early waste placement years), as well as for a potentially large fluctuation in the pond surface elevation due to wet year filling.

The design of the evaporation ponds was accomplished using a water balance calculation and two distinct scenarios, such that different operating conditions were evaluated. The first scenario was pond sizing relative to average conditions approximated by a running 10-year precipitation evaluation to establish the evaporative pond area needed to balance pond inflow with evaporative capacity. The second scenario looked at a sequence of three extreme wet years in a row to evaluate the needed active storage depth to handle the potential higher inflow conditions.

The sensitivity of the recommended evaporation pond design configuration to failure against potential extreme conditions was checked for pond volume and freeboard depth. Pond volume was checked for an average water year with back-to-back 25-year storms. Pond freeboard was checked against wave run-up resulting from a maximum sustained wind speed. This latter calculation was performed under a separate EDF, "Evaporation Pond Berm Overtopping Analysis" (EDF-ER-323).

2. MODEL ASSUMPTIONS

Several assumptions were made in performing the pond sizing water balance. These are discussed below:

1. Landfill Operating Conditions: Two landfill conditions were examined to assess the maximum leachate inputs. It was considered that maximum annual leachate production may occur when either Cell 1 or Cell 2 has only one lift of waste in place. (With more waste in place there will be greater attenuation of leachate flow to the drainage system at the bottom of the landfill.) As explained in the "Leachate Generation Study" (EDF-ER-269), both were compared and it was determined that the Cell 2 open scenario (Cell 2 with one lift in place, Cell 1 closed with an interim cover) would produce the greater annual leachate flow into the evaporation pond. This is true for both the maximum year and average of the 10-year leachate production period studied. Therefore, the sizing of the evaporation pond is based on the Cell 2 open condition.

2. Calculation Time Period: The operational period of the pond is 45 years, per performance specifications (this includes a 15-year period when active waste placement is occurring, and a 30-year post-closure period). This water balance calculation attempts to account for the worst-case scenario during this time. First, the minimum pond surface area is determined using the average leachate production and precipitation to determine the pond evaporative surface area. Then the worst-case condition is simulated using 3 years of maximum year precipitation, following an average year, to determine "surge" storage that may be necessary for unusually high water input to the pond. The surface area is thus optimized to provide no more evaporative surface than necessary for the "long-term" average, while providing storage for fluctuations above the average that will be equalized in the long run.

3. Pond Grading—"Dead" Storage and "Active" Storage: The pond was designed with a graded bottom of 1 to 2% and a volume of greater than 500,000 (250,000 gallons/cell multiplied by 2) according to (DOE-ID 2002a). However, the water balance calculation only considers the volume above the top elevation of the pond bottom. The reason for this is that when trying to predict the water level from one precipitation event to the next when the water surface is near the pond bottom, the timing of these events changes the evaporative surface area. For example, a large precipitation event may fill the shallow graded area causing an enlarged surface area, while long periods of drought may cause the surface area of the pond to shrink. However, since all leachate and precipitation inputs are projected into the future, the starting point for any change in water surface is arbitrary. Lacking a reasonable method to account for the probability of such events, it was thought best to consider the graded area of the ponds from the sump up to the top elevation of the sloped pond bottom as "dead storage." This volume is greater than 500,000 gallons and is thus greater than the initial year input of 300,000 gallons required in the pond design performance specifications. This dead space storage can also handle the 25-year, 24-hour storm event should it occur in the early periods of either the Cell 1 or Cell 2 life cycle when only a small amount of waste is placed and the cell has a very large uncovered (operations and leachate collection layer only) liner area. It should be noted that the sump design also provides versatility in pond sediment management by allowing sediments to be consolidated at the low point of the ponds. This, in turn, can minimize the amount of make-up water needed to keep the sediments covered in the dry operating period of the ponds, as demonstrated later in this EDF.

4. Active Storage: The active storage portion of the evaporation pond, that portion used to determine pond evaporative sizing, begins at the interface between the bottom slope and the side slope. This is the interface between active and dead storage of the pond. The elevation of this interface plane is at the upper elevation of the bottom slope. Effectively, the pond "bottom," as discussed in this

EDF, begins at this location with side slopes of 3:1 above it. Note that the 3:1 slope also causes the surface water area to fluctuate (evaporative surface area increases with increasing leachate level in the pond). This fluctuation was dealt with by defining a rain catchment area and an evaporative surface area (see No. 5 below).

5. Rain Catchment Area /Evaporation Surface Area: This fluctuation in surface area due to 3:1 slope of the active storage was accounted for by taking the ratio of the pond "bottom" to the top of the pond. Although not constant, it is approximately 1.28 for a larger pond considered as a starting point. In the water balance, the bottom area of the active storage area was defined as the evaporation surface area. The ratio was applied to the bottom area in each iteration in the calculation by multiplying the bottom area by 1.28 in each case to arrive at a top area. In the water balance, the top area was defined as the rain catchment area. By taking these measures, the calculation errs on the conservative side where rain catchment is always larger than evaporative area.

6. Minimum Water Surface Depth: The correctly sized pond demonstrates the greatest reduction in water surface depth without the pond going dry. For this water balance calculation, exactly zero in. of water remaining in the pond in one month during the year indicates successful removal. The calculations were iterated until zero water surface depth in one month was just achieved, as described below.

7. Sediment Build-up: Although the pond will be cleaned periodically, sediment build-up was not specifically considered in calculations. In the worst-case make-up water calculation, a 1-in. leachate depth above the dead space storage represents the largest area requiring make-up water to keep the level constant. This allows for a significant amount of sediment storage within the 500,000 gallons (or about 2,500 yd^3) of storage.

8. Liner Leakage: Leakage through the liner was not considered in the water balance in order to assure a conservative estimate of the leachate that will be collected. By neglecting leakage, a water output is taken out of the water balance, more leachate remains in the pond to be evaporated.

9. Sublimation: Sublimation is the evaporation of water from a solid state directly to the atmosphere. It is difficult to accurately predict conditions that would lead to snow accumulation and the length of time in which the snow will remain on the ground and the percentage of melt versus sublimation for a given site. For these reasons, sublimation was not considered in this water balance calculation. In doing so, the model neglects a water output, thus providing a more conservative estimate of water remaining in the pond.

10. Water Balance Equation: The evaporation pond was designed from water budgets in monthly time steps based on design input. The water budget for each time step may be expressed in the following way:

$$\Delta \text{ Evaporation Pond Storage} = \text{direct precipitation falling on pond} + \text{process water inputs} + \text{leachate input} - \text{evaporation output}$$

A description of design criteria and how it was incorporated into the design is described in the following section.

3. DESIGN CRITERIA

3.1 Precipitation on Pond Catchment Area

Daily precipitation data has been recorded at the Central Facilities Area (CFA) at INEEL since 1950. Measurements at other locations in the area, such as the Test Area North (TAN) were also recorded. For the purpose of this study, only CFA precipitation data was used; the CFA averages were higher and therefore represent more conservative design criteria.

Precipitation input selected for the water balance consists of both the average and highest precipitation years from the wettest 10 consecutive precipitation years (1967-1977) recorded period at CFA from the entire data record available from the National Oceanic and Atmospheric Administration (NOAA) station at the INEEL, consistent with the "Leachate Generation Study" (EDF-ER-269). It is recognized that, during the wettest year in this period of record, a drier than normal month could exist. However, the water balance performed for this study examines the storage and evaporative capacity on an annual basis. The previous month's water totals at the end of the month are added to the next month, and so on. In this way, a dry month is offset by wetter months before the year is over.

For a 25-year, 24-hour storm event, the data from Sagendorf 1996 indicate that a storm of this magnitude will produce 1.73 in. of water. For active storage, accounting for a storm of this magnitude was considered to fall within the worst-case annual budget used in the water balance and therefore was not considered separately. For dead storage, both Cell 1 and Cell 2 have an area of about 6.5 acres (Cell 2 is slightly larger). The amount of leachate that could be generated falling on either of these cells early in their life cycle is about 350,000 gallons assuming no attenuation by waste in place. This amount flowing directly to the evaporation pond was considered and the dead space storage has been sized to contain this amount of flow. For the storm impacting (i.e., filling) the pond directly, the amount of freeboard in the design is an order of magnitude greater than the 1.73 in. that would fall on the pond. Section 5 discusses active storage pond depth and freeboard.

3.2 Process Water Inputs

According to performance specifications, the total amount of process water from all facilities including effluent from the Staging, Storage, Sizing, and Treatment Facility (SSSTF) and purge/ development water from Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) groundwater monitoring wells would equal 30,000 gallons per month for the months of March to November.

Additionally, 300,000 gallons would be discharged to the pond during initial start-up. This initial volume will only partially fill the dead storage area described in Section 1 of this EDF at start-up of the facility, which has a volume of 500,000 gallons. For the water balance, the 300,000 gallons does not enter the active storage area. Therefore, this initial amount is not included in the active storage water budget. In the water balance calculation spreadsheet, Appendix A, 30,000 gallons per month was converted to gallons per minute (gpm) (approximately 0.694 gpm), assuming 30 days in a month.

3.3 Leachate Generation

Flow rates for leachate from the ICDF landfill were calculated using a computer program developed by the U.S. Army Corps of Engineers Waterways Experiment Station: Hydraulic Evaluation of Landfill Performance (HELP), version 3.07. The detailed results, modeling assumptions, and inputs for the ICDF HELP Model are presented in the "Leachate Generation Study" (EDF-ER-269). Because the Cell 2 open scenario resulted in the greater leachate production, the leachate flows from this scenario will be used to size the evaporation pond. For determining the evaporative surface area, the average leachate production over the 10-year period modeled will be used. For determining the depth for leachate storage, the maximum year leachate production over the 10-year period modeled will be summed from the maximum year for each of the five trial runs. It is assumed, for determining the pond depth, that active storage (since the wettest year results in leachate gain in the pond, not net evaporation) may be required to handle up to three years in a row of this "worst-case" leachate production. These would be concurrent with the worst-case precipitation years discussed above.

3.4 Evaporation

Evaporation pond water budgets utilized estimates of daily evaporation according to the following relationship:

Pond evaporation = K_1*K_2*(ICDF pan evaporation)

Where K_1 is a pan coefficient, necessary for converting pan data to pond evaporation estimates. A small pond pan coefficient of 0.7 was used for this application, based on the average coefficient shown in the literature (Linsley 1972).

K_2 is a salinity correction coefficient. Evaporation rates are lowered due to the presence of salts in aqueous solution. The liquid stored in the pond will increase in salinity as the water evaporates and salts remain in the pond. Sodium chloride (NaCl) is soluble in water at concentrations of up to 26% by weight. However, due to the presence of rainfall and fresh leachate, the concentration of salt at the pond surface will be less than saturation. A practical maximum concentration for mixed salt salinity suggested by the literature is around 17%, which would lower the vapor pressure of water by about 10% (CRC Handbook 1995), corresponding to a 10% decline in the rate of evaporation. Therefore, a salinity correction coefficient of 0.9 was used for this application regarding the effects that various salts that may be present in the concentrating leachate will have on evaporation. It was assumed that leachate will not contain constituents such as scum or oil that could further lower evaporative rates.

ICDF pan evaporation was determined using monthly pan evaporation from Molnau 1992 for the Aberdeen Experiment Station, the nearest available data to INEEL and applying a correction factor for the site (no pan evaporation data were available for the INTEC facility). The correction factor was determined using a regression analysis of adjusted station altitude from southeastern Idaho (see NOAA December 1989, Figure E-3). The factor was derived from these data by taking the ratio of estimated CFA yearly pan evaporation, reported as 42 in., to the Aberdeen Station 47 in. or 0.89. The correction factor of 0.89 was applied to monthly pan evaporation rates from Molnau.

The above procedure resulted in monthly INEEL pan evaporation values that total to approximately 41 in. per year. Because NOAA (1989) states that the 99% confidence interval for annual evaporation is the range of 40 to 46 in. per year, the computed "average" numbers were considered conservative estimates for the purpose of estimating evaporation in both "worst-case" high precipitation years and under average weather conditions.

3.5 Wave Runup From Sustained Wind

"Evaporation Pond Berm Overtopping Analysis" (EDF-ER-323), evaluated the potential for overtopping of the evaporation pond berm from a sustained design wind. Analysis for wave setup (e.g., change in water surface elevation due to wind stress), wave height and period, and wave runup height was performed to determine the total wave runup elevation reached by the waves surging up the berm slope. The design pond freeboard of 24 in. was checked in the analysis against a design wind speed of 70 mph, and maximum sustained wind speeds were estimated that would be required to overtop the berm. Refer to "Evaporation Pond Berm Overtopping Analysis" (EDF-ER-323) for a detailed description of analytical input, methods of evaluation, and results. Conclusions from the analysis are summarized in Section 5.

4. CALCULATION METHOD

The pond sizing parameters of optimal pond area for evaporation and pond depth for storage were determined in a two-step process. The first step in pond sizing was to determine the optimal pond surface area. The evaporative surface area was selected to allow evaporation of the average leachate production and precipitation onto the pond, as well as required process water inputs. Then the pond depth was selected to provide storage for excess leachate and precipitation that may accumulate if the worst-case leachate and precipitation were to occur for 3 years in a row following an average year.

A spreadsheet was developed (Appendix A) to track the water balance inputs and outputs. In this way, model input could be adjusted by iteration to optimize pond size. This methodology is discussed further below.

4.1 Optimal Pond Surface Area by Iteration

For determining the evaporative surface area, the average precipitation and average leachate production (as described in Section 2) over the modeled 10-year period was used. Evaporation pond sizing was determined using an iterative approach by adjusting the value of the bottom surface area, in square feet in the water balance calculation for an average year. The area was adjusted by trial and error until it just produced a zero water surface for active storage at one point during the year. To account for carryover of water depth from year to year, the resulting water depth in December was determined based on this input. The December total for water depth was added back to the January total in the one-year representative water balance. The process of iteration was then repeated until a surface area was identified that just produced a zero water balance at one point in the year with December's accumulation carried over to January. This area is thus able to consistently evaporate all of the water applied under average conditions.

The surface area is thus optimized to provide no more evaporative surface than necessary for the "long-term" average. The next step is to provide enough depth for storage to accommodate fluctuations above the average that will be equalized in the long run. Determining the depth for leachate storage within the active pond volume is discussed below.

4.2 Pond Depth Adjusted for Higher Than Average Water Inputs

For determining the active volume pond depth, the storage that may be required to handle up to three years in a row of the "worst-case" precipitation and leachate production was used. For three years following one year of average conditions (as described above) the input data were adjusted in the spreadsheet to reflect the worst-case annual precipitation from the 10-year record (as described in Section 2, Design Criteria). The resulting water depth was examined for three years, with carryover of water depth from the first year to the second year and finally to the third year. Adjustments to the pond depth sizing were made to accommodate the excess volume.

The established pond area and depth were checked using a simulated scenario to ensure the sizing was appropriately conservative. A water balance was calculated for the case where back-to-back 25-year storm events and resulting water were pumped to the evaporation pond, occurring in an average year. For this calculation, presented in Appendix B, the 25-year event, totaling 1.73 in. was multiplied by 2 and added to the rainfall monthly total. Each month was tested to determine which would have the largest effect on pond depth. April was determined to be the worst-case month. Also, the volume of water, around 700,000 gallons (see discussion in Section 3.1) from the landfill was added to the pond depth. The dead storage space was assumed to absorb 200,000 gallons of storm water, actual size is around

500,000 gallons, but initial start-up could be as much as 300,000 gallons should this scenario take place in the initial year of operation, or, to be conservative, the storage area is assumed to contain water from previous storm or operation activity. The remaining 500,000 gallons from the two 25-year events were calculated in the pond depth using the established area (see Appendix B).

5. EVAPORATION POND SIZING RESULTS

The calculation spreadsheet is presented in Appendix A. Results are summarized below:

- The optimal surface is approximately 88,000 ft^2. Surface area was adjusted up or down by 1,000 until the water surface depth for average weather conditions was greater than zero for all months but one and reached zero in August.

- The pond depth was adjusted to 64 in. to maintain just over 2 ft of freeboard at the highest simulated water level, given three high years of maximum precipitation and leachate production. The highest observed water level from the three-year period was 39.6 in. in December of the third "worst-case" year. Also note that, if the 25-year, 24-hour precipitation of 1.73 in. were to occur, the water volume resulting from this storm would be about 350,000 gallons from the landfill (assuming no attenuation by operation layers) and an additional 121,000 gallons directly to the pond for a total of 471,000 gallons. Even if this volume of water were to enter the active storage of the pond area—such as the case where the dead storage volume is full from a previous event, process water, or another storm, the total would add less than 9 in. to the depth of water in the pond, and is easily included in the annual water budget.

- The calculation of back-to-back 25-year storm events (Appendix B) occurring in an average year demonstrates the pond can absorb a succession of events of this magnitude with a maximum depth of 25.3 in. The contribution of water to the pond from the three-year worst-case scenario, used to establish a conservative pond depth was greater, around 39.6 in.

- From "Evaporation Pond Berm Overtopping Analysis" (EDF-ER-323), the runup estimated for the 70-mph design wind and maximum design water depth of 4 ft is 8 in. above pond stillwater elevation. This corresponds to 2.3 ft below the crest of the berm, based on the current pond configuration. It is estimated that a sustained wind in excess of 200 mph would be required to create runup elevations reaching the berm crest elevation. At 200 mph, the runup elevation is estimated at 1 ft below the berm crest elevation. The most reasonable conclusion is that the wave runup will not overtop the crest of the berm under any conceivable wind speed at the project site. Therefore, the 2 ft of freeboard required by the regulations is adequate to prevent overtopping.

The final pond sizing was found to be 88,000 ft^2 for the pond bottom and 112,552 ft^2 for the pond top with an overall depth of 64 in. for the active storage area. Depth and dimensions of the graded area of the pond, dead storage, may be found in the Area Final Grading Plan, Drawing C-203, Evaporation Pond Area Final Grading Plan (DOE-ID 2002b). Based on the representative model presented in this EDF, a pond with these dimensions is optimally sized to handle the maximum expected inflow.

6. MAKE-UP WATER

ICDF Performance Specifications (SPC-332) require that pond sediments remain submerged at all times to prevent the release of dust to the atmosphere. To meet this requirement, it will be necessary to use make-up water. This is especially true when dry periods of precipitation and low leachate flow prevail.

The ponds are designed to economize raw make-up water by utilizing the sloped portion of the pond bottom, which is the dead storage area. Pond sediments may be washed down to the lowest possible point in the pond, eliminating the need to keep the entire dead storage area filled. Depending on the depth of the sediments, the exposed surface area may range from very small, covering only the lowest sump area of the pond, to large, filling the entire surface area of the dead storage area. It was assumed that no sediments would be present in the active storage area of the pond.

To determine make-up water needs, two cases were examined: the maximum water need, where the exposed surface area of the sediments includes the extent of the pond bottom area (i.e., the top of the dead storage area) and the case where the dead storage area is half-full of sediments, to a depth of approximately 1.5 ft (which reduces the top evaporation area by about half). In doing so, a range of make-up water needs was established.

6.1 Design Criteria Modified

Water balance calculations like those performed for the pond sizing were used to determine make-up needs. However, since the dry season represents the worst-case scenario for make-up water needs, it was necessary to consider the case where less than average precipitation prevails. Several modifications were made to the calculation inputs to accomplish this task.

6.1.1 Precipitation

The precipitation input was adjusted to reflect a dry year. The chosen year was the driest year from the 10-year period described earlier in this EDF, year 8 from the "Leachate Generation Study" (EDF-ER-269). To ensure that the selected year represented dryer than average conditions, the yearly total was compared to historical data from the CFA. The dry precipitation year (year 6, 1972) had an average of 7.43 in. The average yearly total at CFA was 8.63 in., a difference of 1.20 in.

6.1.2 Leachate

Less than average leachate input was also desired to calculate make-up water needs. From the HELP models in "Leachate Generation Study" (EDF-ER-269), the lowest leachate year for each of the HELP runs ("Leachate Generation Study," Section 2 [EDF-ER-269]) was determined from annual totals in the 10-year simulation. The leachate was input on a monthly basis into the water balance.

6.1.3 Evaporation

Evaporation input to the water balance was not modified for the purpose of determining make-up water needs. The evaporation data used in the pond sizing from Molnau represent average values adjusted to be site specific. However, as discussed above, the range of evaporation between dry and wet years is relatively small compared to precipitation and leachate flow, and the computed average for these simulations is near the low end of the 99% confidence interval for range of annual evaporation. For these reasons the evaporation input was left unchanged in the water balance.

NOTE: Process water input was assumed to remain per performance specifications 30,000 gallons per month from March to November.

6.2 Calculation Method

Make-up water was calculated in the following way. Make-up water was added to the water balance calculation as a water *input* along with the modified design criteria. Values were input to make-up water by trial and error to maintain a minimal water level, selected as 1 in. of water in the pond. This procedure was repeated for the two scenarios described below to find the range of possible make-up water needs.

6.2.1 Maximum Raw Make-up Water

To establish the maximum raw make-up water needs, it was assumed that the entire dead storage area of the pond was filled with sediments, or must be maintained wet. The water required to maintain 1 in. submersion of these sediments (over a bottom area of 88,000 ft^2) was determined using the water balance calculation spreadsheet Make-Up Water in Appendix A (Tables A-8 and A-9). Water depth was examined to determine when the depth went negative (the spreadsheet was modified to reflect negative surface depth for the purpose of finding a water deficit for any given month).

6.2.2 Low Range Make-up Water

For the lower range of make-up water needs, it was assumed that the sediments filled the dead storage area of the pond to a depth of 1.5 ft. The resulting exposed surface area of the sediments was calculated from Draft Title I design drawing and found to be approximately 44,000 ft^2. The value of 44,000 ft^2 was input to the calculation spreadsheet as the evaporative surface area (i.e., the bottom of the pond with sediments in place). It should be noted that this adjusted surface area was input only for the months of July, August, September, and October since decreasing the evaporative surface area for the entire year actually increases the water level in the calculation (by reducing the evaporative capacity of the pond). By selecting a shortened period when the pond is reduced to a low level, below the active storage area, a lower estimate for make-up water needs is generated (see Appendix A, Tables A-10 and A-11).

6.3 Raw Make-up Water Results

Results from the make-up water calculations presented in Appendix A, Make-up Water Maximum Range and Make-up Water Low Range are as follows:

Make-up Water Maximum Range: 5.93 gpm for July; Between 0.24 and 4.71 gpm for May, June, August, September, and October

Make-up Water Low Range: 2.39 gpm for July; Between 0.08 and 1.32 gpm for June, August, and September

The results indicate that, between 1 and 6 gpm (rounding up) may be necessary for the period of May to October. The amount of water required to wash the sediments down the slope of the pond was not considered. This wash water amount is considered negligible, however, due to the infrequency of the anticipated washdown periods.

7. REFERENCES

40 CFR 264.221, 1992, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," Section 221, "Design and operating requirements," *Code of Federal Regulations*, Office of the Federal Register, January 1, 1992.

CRC, 1995, *Handbook of Chemistry and Physics*, 82nd edition, CRC Press.

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Appendix A

Water Surface Depth Calculation

Table A-1. ICDF Leachate Evaporation Pond Calculations.

		May	June	July	August	Sept	Oct	Annual
Aberdeen Evap. (Ref. 1)	5-yr.Avg.	7.58	9.01	10.36	9.42	6.46	3.37	46.20
INEL Pan Evap. (Ref. 2)		6.75	8.02	9.22	8.38	5.75	3.00	41.12
Aberdeen to INEEL Factor		0.89	See p. 93 of Ref. 2					
Pan Coefficient		0.7	Ratio of Pond Evap to Pan Evap for Fresh Water					
Salinity correction factor		0.9	Ratio of Saline Evap to Fresh water Evap					
Pond Surface Area at Top		112,552	ft2					
Pond Surface Area at Floor		88,000	ft2					
Ratio		1.279						

Table A-2. Evap. Pond Simulation for average of 10 wettest year precip. and leachate production - long term average. Cell 2 open with one 10-ft. lift in place, Cell 1 closed with 2-ft. cover soil.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Rainfall (inches)	0.88	0.46	0.69	0.75	0.89	1.55	0.39	0.70	0.65	0.69	0.77	0.84	9.26
Leachate Flow (gpm)	0.5872	0.4993	0.436	0.5633	1.1746	1.877	1.1166	0.8999	0.9678	1.061	1.155	0.791	
Process Water Flow (gpm)[a]	0	0	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0	6.25
Rainfall Flow	1.38	0.80	1.08	1.22	1.40	2.52	0.61	1.10	1.06	1.08	1.25	1.32	
Total (gpm)	1.97	1.30	2.21	2.48	3.27	5.09	2.42	2.69	2.72	2.84	3.10	2.11	
Total (gpd)	2,837	1,872	3,189	3,564	4,705	7,327	3,490	3,879	3,913	4,089	4,463	3,040	
Avg Pan Evap (inches)	0	0	0	0.00	6.75	8.02	9.22	8.38	5.75	3.00	0.00	0.00	41
Avg Pond Evap (inches)	0	0	0	0.00	4.25	5.05	5.81	5.28	3.62	1.89	0	0	25.90
Assumed Rain Catchment Area	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	
Assumed Evap Surface Area	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	
Liquid Added to Pond (gallons)	87,951	52,404	98,852	106,933	145,854	219,811	108,187	120,262	117,392	126,752	133,898	94,242	1,412,539
Evap from Pond (gallons)	0	0	0	0	233,132	277,114	318,635	289,724	198,685	103,649	0	0	1,420,939
Liquid Added to Pond (inches)	1.60	0.96	1.80	1.95	2.66	4.01	1.97	2.19	2.14	2.31	2.44	1.72	25.75
Water Surface Depth (inches)[b]	6.2	7.2	9.0	10.9	9.3	8.3	4.4	1.3	0.0	0.4	2.9	4.6	
Freeboard (inches)	57.8	56.8	55.0	53.1	54.7	55.7	59.6	62.7	64.0	63.6	61.1	59.4	
Pond Depth (inches)[c]	64.0												

[a] Assumes 30,000 gallons added per month March thru November, per 5.6.4.1 of Perf. Specs. (Initial 300,000 gallon addition assumed to occupy dead storage provided in sloped pond bottom.

[b] Initial water surface depth in January is depth in average year December plus January additions

[c] Active storage pond depth

Table A-3. Evap. Pond Simulation for worst case - highest precip. year from 10 wettest year period and highest leachate production year from each area. Cell 2 open with one 10-ft lift, Cell 1 closed.

Year 1	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Worst Case Rainfall (inches)	0.55	0.20	0.33	0.11	1.49	3.89	0.05	3.27	0.85	0.34	0.88	1.29	13.25
Leachate Flow (gpm)	0.8946	0.7912	0.699	0.714	1.3393	4.6245	1.4332	3.0755	1.3604	1.5958	1.8151	1.2116	
Process Water Flow (gpm)[a]	0	0	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0	
Rainfall Flow	0.86	0.35	0.52	0.18	2.34	6.32	0.08	5.14	1.38	0.53	1.43	2.03	
Total (gpm)	1.76	1.14	1.91	1.59	4.38	11.64	2.21	8.91	3.43	2.82	3.94	3.24	
Total (gpd)	2,533	1,640	2,753	2,285	6,300	16,756	3,176	12,829	4,946	4,067	5,671	4,664	
Avg Pan Evap (inches)	0	0	0	0.00	6.75	8.02	9.22	8.38	5.75	3.00	0.00	0.00	41
Avg Pond Evap (inches)	0	0	0	0.00	4.25	5.05	5.81	5.28	3.62	1.89	0.00	0.00	25.90
Assumed Rain Catchment Area	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	
Assumed Evap Surface Area	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	
Liquid Added to Pond (gallons)	78,522	45,933	85,335	68,543	195,301	502,672	98,466	397,685	148,384	126,070	170,132	144,589	2,061,631
Evap from Pond (gallons)	0	0	0	0	233,132	277,114	318,635	289,724	198,685	103,649	0	0	1,420,939
Liquid Added to Pond (inches)	1.43	0.84	1.56	1.25	3.56	9.16	1.80	7.25	2.71	2.30	3.10	2.64	37.58
Water Surface Depth (inches)[b]	6.0	6.8	8.4	9.7	9.0	13.1	9.1	11.0	10.1	10.5	13.6	16.3	
Freeboard (inches)	58.0	57.2	55.6	54.3	55.0	50.9	54.9	53.0	53.9	53.5	50.4	47.7	
Pond Depth (inches)	64.0												

[a]Assumes 30,000 gal added per mo Mar thru Nov per 5.6.4.1 of Perf. Specs.

[b]Initial water surface depth in January is December depth from previous year plus January additions

Table A-4. Evap. Pond Simulation for worst case - highest precip. year from 10 wettest year period and highest leachate production year from each area. Cell 2 open with one 10-ft lift, Cell 1 closed.

Year 2	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Worst Case Rainfall (inches)	0.55	0.20	0.33	0.11	1.49	3.89	0.05	3.27	0.85	0.34	0.88	1.29	13.25
Leachate Flow (gpm)	0.8946	0.7912	0.699	0.714	1.3393	4.6245	1.4332	3.0755	1.3604	1.5958	1.8151	1.2116	
Process Water Flow (gpm)[a]	0	0	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0	
Rainfall Flow	0.86	0.35	0.52	0.18	2.34	6.32	0.08	5.14	1.38	0.53	1.43	2.03	
Total (gpm)	1.76	1.14	1.91	1.59	4.38	11.64	2.21	8.91	3.43	2.82	3.94	3.24	
Total (gpd)	2,533	1,640	2,753	2,285	6,300	16,756	3,176	12,829	4,946	4,067	5,671	4,664	
Avg Pan Evap (inches)	0	0	0	0.00	6.75	8.02	9.22	8.38	5.75	3.00	0.00	0.00	41
Avg Pond Evap (inches)	0	0	0	0.00	4.25	5.05	5.81	5.28	3.62	1.89	0.00	0.00	25.90
Assumed Rain Catchment Area	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	
Assumed Evap Surface Area	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	
Liquid Added to Pond (gallons)	78,522	45,933	85,335	68,543	195,301	502,672	98,466	397,685	148,384	126,070	170,132	144,589	2,061,631
Evap from Pond (gallons)	0	0	0	0	233,132	277,114	318,635	289,724	198,685	103,649	0	0	1,420,939
Liquid Added to Pond (inches)	1.43	0.84	1.56	1.25	3.56	9.16	1.80	7.25	2.71	2.30	3.10	2.64	37.58
Water Surface Depth (inches)[b]	17.7	18.5	20.1	21.3	20.6	24.8	20.7	22.7	21.8	22.2	25.3	27.9	
Freeboard (inches)	46.3	45.5	43.9	42.7	43.4	39.2	43.3	41.3	42.2	41.8	38.7	36.1	
Pond Depth (inches)	64.0												

[a]Assumes 30,000 gal added per mo Mar thru Nov per 5.6.4.1 of Perf. Specs.

[b]Initial water surface depth in January is December depth from previous year plus January additions

Table A-5. Evap. Pond Simulation for worst case - highest precip. year from 10 wettest year period and highest leachate production year from each area. Cell 2 open with one 10-ft lift, Cell 1 closed.

Year 3	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Worst Case Rainfall (inches)	0.55	0.20	0.33	0.11	1.49	3.89	0.05	3.27	0.85	0.34	0.88	1.29	13.25
Leachate Flow (gpm)	0.8946	0.7912	0.699	0.714	1.3393	4.6245	1.4332	3.0755	1.3604	1.5958	1.8151	1.2116	
Process Water Flow (gpm)[a]	0	0	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0	
Rainfall Flow	0.86	0.35	0.52	0.18	2.34	6.32	0.08	5.14	1.38	0.53	1.43	2.03	
Total (gpm)	1.76	1.14	1.91	1.59	4.38	11.64	2.21	8.91	3.43	2.82	3.94	3.24	
Total (gpd)	2,533	1,640	2,753	2,285	6,300	16,756	3,176	12,829	4,946	4,067	5,671	4,664	
Avg Pan Evap (inches)	0	0	0	0.00	6.75	8.02	9.22	8.38	5.75	3.00	0.00	0.00	41
Avg Pond Evap (inches)	0	0	0	0.00	4.25	5.05	5.81	5.28	3.62	1.89	0.00	0.00	25.90
Assumed Rain Catchment Area	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	
Assumed Evap Surface Area	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	
Liquid Added to Pond (gallons)	78,522	45,933	85,335	68,543	195,301	502,672	98,466	397,685	148,384	126,070	170,132	144,589	2,061,631
Evap from Pond (gallons)	0	0	0	0	233,132	277,114	318,635	289,724	198,685	103,649	0	0	1,420,939
Liquid Added to Pond (inches)	1.43	0.84	1.56	1.25	3.56	9.16	1.80	7.25	2.71	2.30	3.10	2.64	37.58
Water Surface Depth (inches)[b]	29.4	30.2	31.8	33.0	32.3	36.4	32.4	34.4	33.5	33.9	37.0	39.6	
Freeboard (inches)	34.6	33.8	32.2	31.0	31.7	27.6	31.6	29.6	30.5	30.1	27.0	24.4	
Pond Depth (inches)	64.0												

[a]Assumes 30,000 gal added per mo Mar thru Nov per 5.6.4.1 of Perf. Specs.
[b]Initial water surface depth in January is December depth from previous year plus January additions

REFERENCES
1. Molnau, M., 1992.
2. NOAA, 1989.

Table A-6. ICDF Leachate Evaporation Pond Calculations (Table A-1 information repeated for use with Table A-7).

		May	June	July	August	Sept	Oct	Annual
Aberdeen Evap. (Ref. 1)	5-yr.Avg.	7.58	9.01	10.36	9.42	6.46	3.37	46.20
INEL Pan Evap. (Ref. 2)		6.75	8.02	9.22	8.38	5.75	3.00	41.12
Aberdeen to INEEL Factor		0.89	See p. 93 of Ref. 2					
Pan Coefficient		0.7	Ratio of Pond Evap to Pan Evap for Fresh Water					
Salinity correction factor		0.9	Ratio of Saline Evap to Fresh water Evap					
Pond Surface Area at Top		112,552	ft2					
Pond Surface Area at Floor		88,000	ft2					
Ratio		1.279						

Table A-7. Evap. Pond Simulation for average of 10 wettest year precip. and leachate production with two 25-Year storm events occuring in April. Cell 2 open with one 10-ft. lift in place, Cell 1 closed with 2-ft. cover soil.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Rainfall (inches)	0.88	0.46	0.69	4.21	0.89	1.55	0.39	0.70	0.65	0.69	0.77	0.84	12.72
Leachate Flow (gpm)	0.5872	0.4993	0.436	0.5633	1.1746	1.877	1.1166	0.8999	0.9678	1.061	1.155	0.791	
Process Water Flow (gpm)[a]	0	0	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0	6.25
Rainfall Flow	1.38	0.80	1.08	6.84	1.40	2.52	0.61	1.10	1.06	1.08	1.25	1.32	20.44
Total (gpm)	1.97	1.30	2.21	8.09	3.27	5.09	2.42	2.69	2.72	2.84	3.10	2.11	
Total (gpd)	2,837	1,872	3,189	11,656	4,705	7,327	3,490	3,879	3,913	4,089	4,463	3,040	
Avg Pan Evap (inches)	0	0	0	0.00	6.75	8.02	9.22	8.38	5.75	3.00	0.00	0.00	41
Avg Pond Evap (inches)	0	0	0	0.00	4.25	5.05	5.81	5.28	3.62	1.89	0	0	25.90
Assumed Rain Catchment Area	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	
Assumed Evap Surface Area	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	
Liquid Added to Pond (gallons)	87,951	52,404	98,852	349,678	145,854	219,811	108,187	120,262	117,392	126,752	133,898	94,242	1,655,284
Evap from Pond (gallons)	0	0	0	0	233,132	277,114	318,635	289,724	198,685	103,649	0	0	1,420,939
Liquid Added to Pond (inches)	1.60	0.96	1.80	6.37	2.66	4.01	1.97	2.19	2.14	2.31	2.44	1.72	30.18
Water Surface Depth (inches)[b]	6.2	7.2	9.0	15.3	13.7	12.7	8.9	5.8	4.3	4.7	7.2	8.9	
Freeboard (inches)	57.8	56.8	55.0	48.7	50.3	51.3	55.1	58.2	59.7	59.3	56.8	55.1	
Pond Depth (inches)(3)	64.0												

[a]Assumes 30,000 gallons added per month March thru November, per 5.6.4.1 of Perf. Specs. (Initial 300,000 gallon addition assumed to occupy dead storage provided in sloped pond bottom.

[b]Initial water surface depth in January is depth in average year December plus January additions

[c]Active storage pond depth.

Table A-8. Make-up Water Maximum - ICDF Leachate Evaporation Pond Calculations (Table A-1 information repeated for use with Table A-9).

		May	June	July	August	Sept	Oct	Annual
Aberdeen Evap. (Ref. 1)	5-yr.Avg.	7.58	9.01	10.36	9.42	6.46	3.37	46.20
INEL Pan Evap. (Ref. 2)		6.75	8.02	9.22	8.38	5.75	3.00	41.12
Aberdeen to INEEL Factor		0.89	See p. 93 of Ref. 2					
Pan Coefficient		0.7	Ratio of Pond Evap to Pan Evap for Fresh Water					
Salinity Correction Factor		0.9	Ratio of Saline Evap to Fresh Water Evap					
Pond Surface Area at Top		112,552	ft2					
Pond Surface Area at Floor		88,000	ft2					
Ratio		1.279						

Table A-9. Evap. Pond Simulation for Dry Year in 10 year simulation period - Cell 2 with one lift of waste in place.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Dry Year Rainfall (inches)	0.48	0.09	0.25	0.35	0.65	1.42	0.32	0.73	0.55	0.75	0.76	1.08	7.43
MAKE UP WATER ADDED TO THE WATER BALANCE AS A DIRECT INPUT--AMOUNT ADJUSTED UNTIL MINIMUM WATER SURFACE DEPTH = 1"													
Makeup water added (inches)					0.92	2.10	3.65	2.90	1.70	0.15			
Makeup water added (gpm)					1.49	3.41	5.93	4.71	2.76	0.24			
Leachate Flow (gpm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.18	0.22	0.33	0.26	
Process Water Flow (gpm)	0	0	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0	6.25
Rainfall Flow	0.75	0.16	0.39	0.57	1.02	2.31	0.50	1.15	0.89	1.18	1.23	1.70	
Total (gpm)	0.75	0.16	1.09	1.26	3.21	6.41	7.12	6.56	4.53	2.34	2.26	1.96	
Total (gpd)	1,086	226	1,565	1,818	4,622	9,231	10,259	9,444	6,526	3,364	3,248	2,815	
Avg Pan Evap (inches)	0	0	0	0.00	6.75	8.02	9.22	8.38	5.75	3.00	0.00	0.00	41
Avg Pond Evap (inches)	0	0	0	0.00	4.25	5.05	5.81	5.28	3.62	1.89	0	0	25.90
Assumed Rain Catchment Area	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	
Assumed Evap Surface Area	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	88,000	
Liquid Added to Pond (gallons)	33,676	6,314	48,520	54,536	143,279	276,935	318,041	292,768	195,779	104,298	97,431	87,274	1,658,850
Evap from Pond (gallons)	0	0	0	0	233,132	277,114	318,635	289,724	198,685	103,649	0	0	1,420,939
Liquid Added to Pond (inches)	0.61	0.12	0.88	0.99	2.61	5.05	5.80	5.34	3.57	1.90	1.78	1.59	30.24
Water Surface Depth (inches)	0.6	0.7	1.6	2.6	1.0	1.0	1.0	1.0	1.0	1.0	2.7	4.3	
Freeboard (inches)	73.4	73.3	72.4	71.4	73.0	73.0	73.0	73.0	73.0	73.0	71.3	69.7	
Pond Depth (inches)	74.0												

**Calculated from the dryest leachate producing years from the 10-year HELP trial period. See EDF Section 6.1.2.

REFERENCES
1. Molnau, M., 1992.
2. NOAA, 1989

Table A-10. Make-up Water Minimum - ICDF Leachate Evaporation Pond Calculations (Table A-1 repeated for use with Table A-11).

		May	June	July	August	Sept	Oct	Annual
Aberdeen Evap. (Ref. 1)	5-yr.Avg.	7.58	9.01	10.36	9.42	6.46	3.37	46.20
INEL Pan Evap. (Ref. 2)		6.75	8.02	9.22	8.38	5.75	3.00	41.12
Aberdeen to INEEL Factor		0.89	See p. 93 of Ref. 2					
Pan Coefficient		0.7	Ratio of Pond Evap to Pan Evap for Fresh Water					
Salinity Correction Factor		0.9	Ratio of Saline Evap to Fresh Water Evap					
Pond Surface Area at Top		112,552	ft2					
Pond Surface Area at Floor		88,000	ft2					
Ratio		1.279						

Table A-11. Evap. Pond Simulation for Dry Year in 10 year simulation period - Cell 2 with one lift of waste in place.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Dry Year Rainfall (inches)	0.48	0.09	0.25	0.35	0.65	1.42	0.32	0.73	0.55	0.75	0.76	1.08	7.43
MAKE UP WATER ADDED TO THE WATER BALANCE AS A DIRECT INPUT--AMOUNT ADJUSTED UNTIL MINIMUM WATER SURFACE DEPTH = 1"													
Makeup water added (inches)						0.05	1.47	0.85	0.35				
Makeup water added (gpm)						**0.08**	**2.39**	**1.38**	**0.57**				
Leachate Flow (gpm)**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.18	0.22	0.33	0.26	
Process Water Flow (gpm)	0	0	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0	6.25
Rainfall Flow	0.75	0.16	0.39	0.57	1.02	2.31	0.50	1.15	0.89	1.18	1.23	1.70	
Total (gpm)	0.75	0.16	1.09	1.26	1.72	3.08	3.58	3.23	2.34	2.09	2.26	1.96	
Total (gpd)	1,086	226	1,565	1,818	2,470	4,437	5,161	4,650	3,369	3,014	3,248	2,815	
Avg Pan Evap (inches)	0	0	0	0.00	6.75	8.02	9.22	8.38	5.75	3.00	0.00	0.00	41
Avg Pond Evap (inches)	0	0	0	0.00	4.25	5.05	5.81	5.28	3.62	1.89	0	0	25.90
Assumed Rain Catchment Area	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	112,552	
Assumed Evap Surface Area	88,000	88,000	88,000	88,000	44,000	44,000	44,000	44,000	44,000	44,000	84,000	84,000	
Liquid Added to Pond (gallons)	33,676	6,314	48,520	54,536	76,582	133,112	160,000	144,151	101,067	93,423	97,431	87,274	1,036,086
Evap from Pond (gallons)	0	0	0	0	116,566	138,557	159,317	144,862	99,343	51,824	0	0	710,470
Liquid Added to Pond (inches)	0.61	0.12	0.88	0.99	2.79	4.85	5.83	5.26	3.68	3.41	1.86	1.67	31.96
Water Surface Depth (inches)	0.6	0.7	1.6	2.6	1.1	1.0	1.0	1.0	1.0	2.5	4.4	6.1	
Freeboard (inches)	73.4	73.3	72.4	71.4	72.9	73.0	73.0	73.0	73.0	71.5	69.6	67.9	
Pond Depth (inches)	74.0												

**Calculated from the dryest leachate producing years from the 10-year HELP trial period. See EDF Section 6.1.2.

REFERENCES
1. Molnau, M., 1992.
2. NOAA, 1989.

THE CONTENTS OF THIS SECTION ARE
THE HIGHEST QUALITY AVAILABLE

INITIAL gj DATE 9/27/02

PAGE NUMBERING SEQUENCE IS INCONSISTENT

Appendix B

25-Year Storm Event Calculation

CH2MHILL SUBJECT ICDF EDF 271 BY Dean Bose
2 25-YEAR 24-HOUR STORM SHEET NO. ___ OF ___ DATE 07-06-01
Water Balance Supplement PROJECT NO. ___

Determine: Effect of 2 back-to-back 25 Year 24 hour Storms at ICDF on pond depth

Assumed Inputs:

Volume dead storage available = 200,000 gallons

Volume of water resulting from 2 storms = 700,000 gallons

Solution:

① Find pond depth resulting from 500,000 gallons pumped to the ponds (700,000 gal − 200,000 gal)

From pond sizing calculations: A = 88,000 ft^2 bottom
112,500 ft^2 top
D = 64 inches

D_{water} = Volume / Area

$= 500{,}000 \text{ gallons} \cdot \frac{0.13368\ ft^3}{1 \text{ gallon}} \cdot \frac{1}{88{,}000\ ft^2}$

$= 0.84$ ft = 10 inches

② Using water balance in Appendix A, 25-Year event × 2 = 1.73 × 2 = 3.46" added to monthly total (April) for average year:

D_{max} = 15.3 inches

Total contribution from ① and ② is 25.3 inches. Pond depth was chosen as 64.0 inches.

Note: Contribution from two back to back storm events is less than that from 3 back to back years of maximum rainfall (D_{max} = 39.6 inches). The latter was used to select freeboard depth so that 2 feet freeboard was available.

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